Moon Exploration with FUSIO RT

A scalable and configurable computer core

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AGENDA

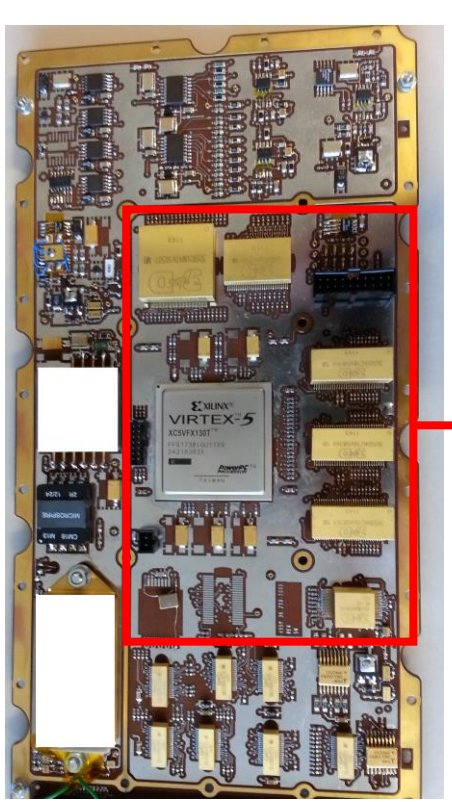
FUSIO RT - A scalable and configurable computer core

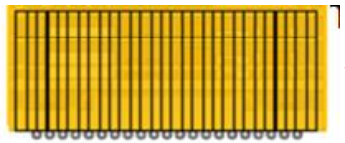
- Genesis of the FUSIO RT Product Line
- FUSIO RT Modules Key Features
- FUSIO RT Modules Development Tools and Ecosystem
- FUSIO RT on the Moon (DORN Mission)
- Conclusion and Introduction to FULTRA

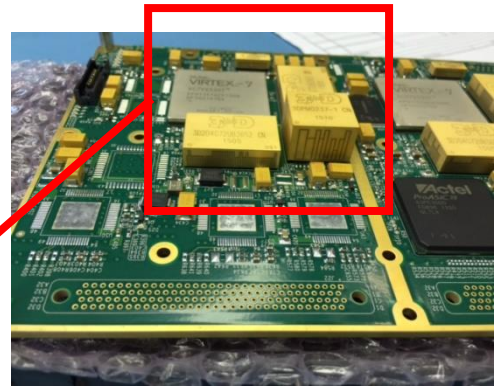
GENESIS OF THE FUSIO RT PRODUCT LINE

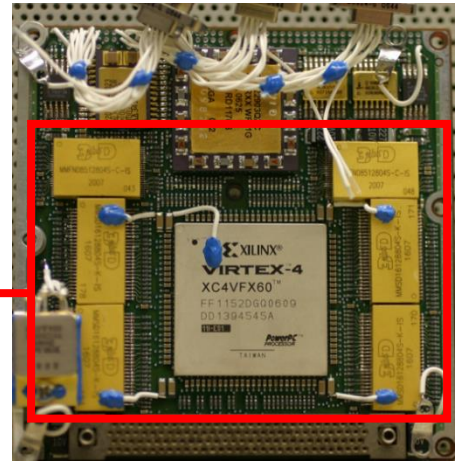
Flexible and Versatile Solution to Address Multiple Applications with one Generic Module

- Most space computer boards or processing units have the same architectural design:









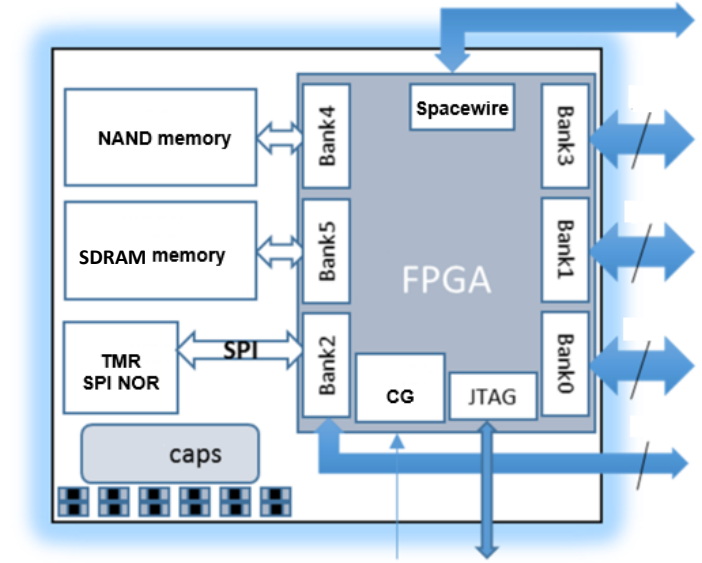
SRAM based FPGA
with boot memory
With computing memory and storage memory
in one single module

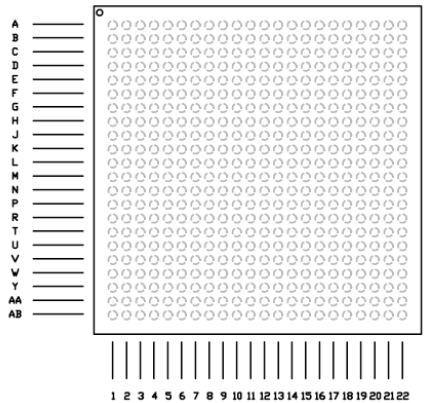
- FUSIO RT proposes a programmable all-in-one space computing core, miniaturized, Radiation Hardened by design, fully qualified and ready-to-use for fast development of Space Applications.

FUSIO RT COMPUTER CORE MODULE

Electrical Architecture and Key Features

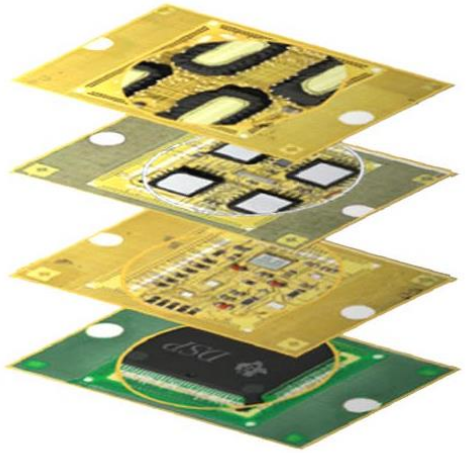
- **4M Gate FPGA NG-Medium NX1H35S from NanoXplore**
- 128 Mb TMR SPI NOR Flash for SEE immune bitstream memory with embedded power switch
- 2 Gb SDRAM – 32b computing memory integrated
- 64 Gb Nand Flash – 32b mass memory integrated
- 263 user I/Os (3.3V, 1.8V & 1.5V) available
- Temperature range: -55 to +105°C
- BGA484 1.27pitch, LxWxH: 32x32x10mm
- Space qualified technologies & All-in-one solution
- Module Radiation Tolerance:
  - Total ionizing dose > 50Krads
  - SEL immune up to LET > 60MeV.cm2/mg.
- ITAR Free



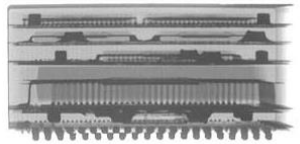


FUSIO RT COMPUTER CORE MODULE

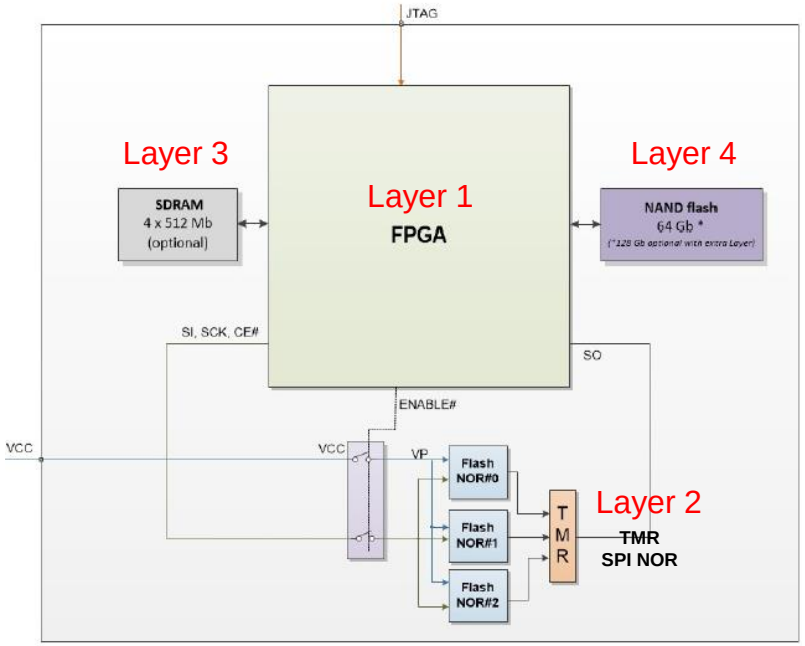
Modular Scalable Architecture with 3D Stacking Packaging Technology

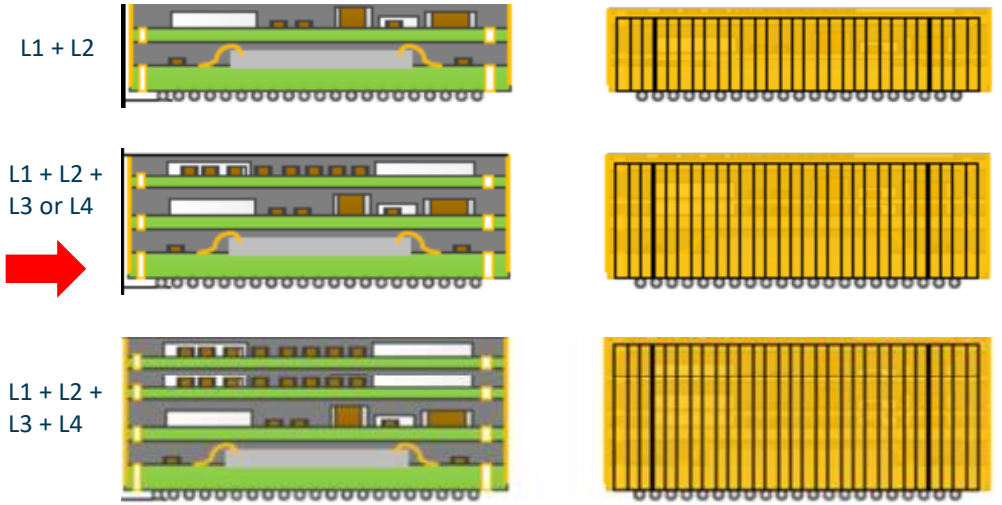


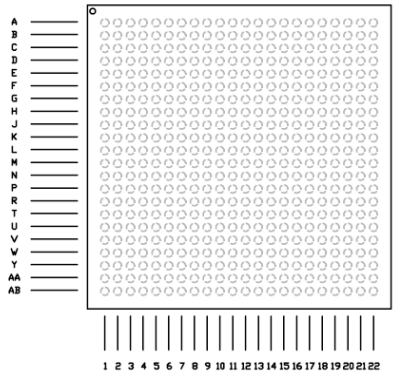
External view
with vertical electrical interconnection



X-Ray inside view
of the stacked layers







BGA484 1.27pitch, LxWxH: 32x32x10mm

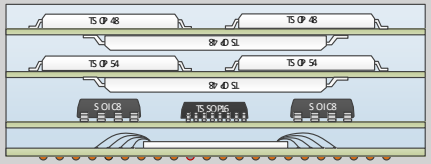
All configurations have the same footprint

FUSIO RT PRODUCT FAMILY

A Product Definition Tailored to the Application's Needs

3DMC0752 – 4 layers

Full Configuration
(FPGA + configuration memory + 2Gbit SDRAM + 64 Gbit NAND Flash)



3DMC0753 – 2 layers

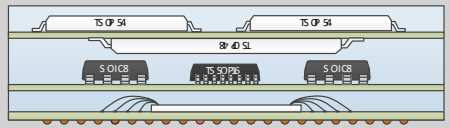
Basic configuration
(FPGA + configuration memory)

3DMC0754 – 3 layers

Basic configuration + 64 Gbit NAND Flash

3DMC0755 – 3 layers

Basic configuration + 2 Gbit SDRAM



All FUSIO RT Products P/Ns have the same footprint

FUSIO RT PRODUCT FAMILY

Development Tools and Ecosystem for Easy and Fast Application's Prototyping

- **FPGA Development Tools**
  - NanoXplore Software Development Ecosystem
- **3DEV FUSIO RT Development Kits**
  - Ready to use development board for early prototyping
  - Compatible with all 4 FUSIO RT configurations (3DEV0752 to 3DEV0755)
- **IP Cores for Embedded Memory Control and Radiation Protection**
  - RIMC SDRAM memory controller for 3DMC0752 and 3DMC0755
  - RIMC NAND Flash memory controller for 3DMC0752 and 3DMC0754
  - RIMC DDR2 memory controller for external DDR2 Memory
  - RIMC SDRAM and NAND Flash provided with the product
- **Power management solutions**
  - Dedicated Application Note for power management using 3D PLUS 3DPM0289 PoL solution

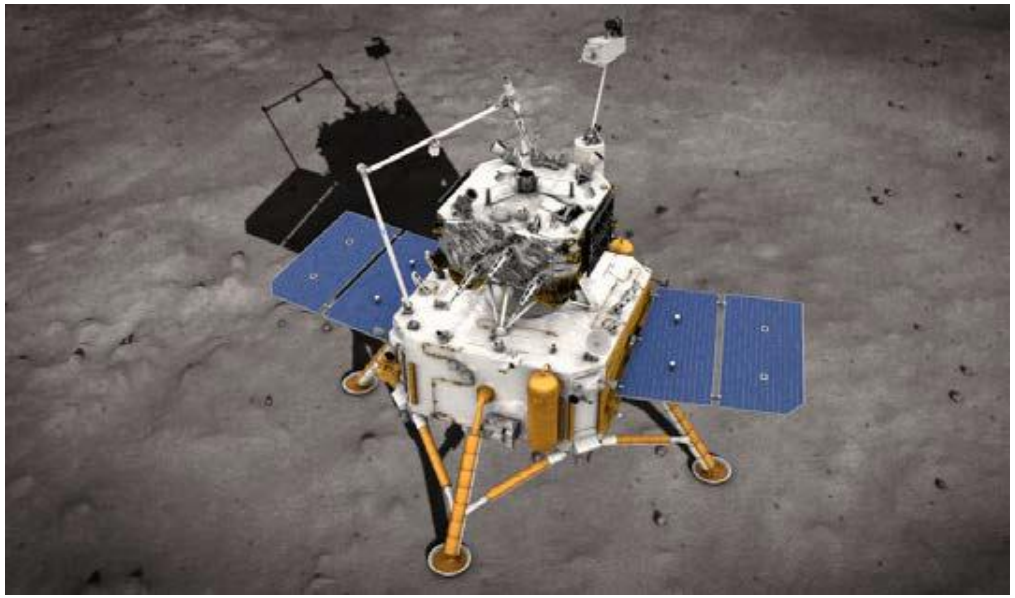
Development board 3DEV0753

FUSIO RT ON THE MOON

DORN Instrument Developed by IRAP in France

- DORN instrument is dedicated to measuring radon on the moon within Chang'e 6 mission.

- The Chang'e 6 probe, consisting of an orbiter, lander, lunar ascent vehicle and reentry capsule, will target the South Pole-Aitken (SPA) basin located on the far side of the moon in 2024.

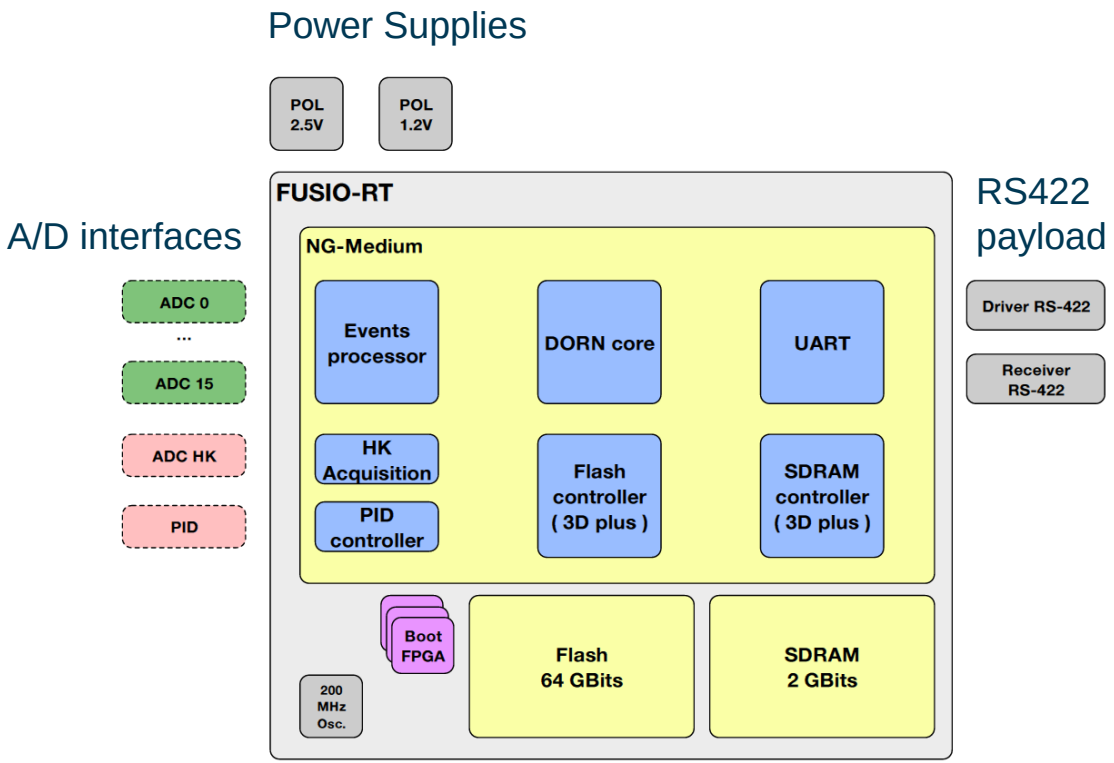


- DORN Project Constraints and Instrument Key requirements:
  - Fast Project: 3 years from KO to delivery in June 2023
    - Easy-to-use components for quick development time
    - Space qualification pedigree
  - High Performance / Low Power
    Acquisition of Radon spectra by 8 detection heads at 15000 evts/s
  - Volume: very small size and compact instrument design
  - Export Control: Launch from China will be easier with ITAR Free components

FUSIO RT ON THE MOON

DORN Instrument Architecture – FUSIO RT Module Key Functions

- FUSIO RT @ 100 MHz with SDRAM and NAND Flash is selected for the instrument controller board

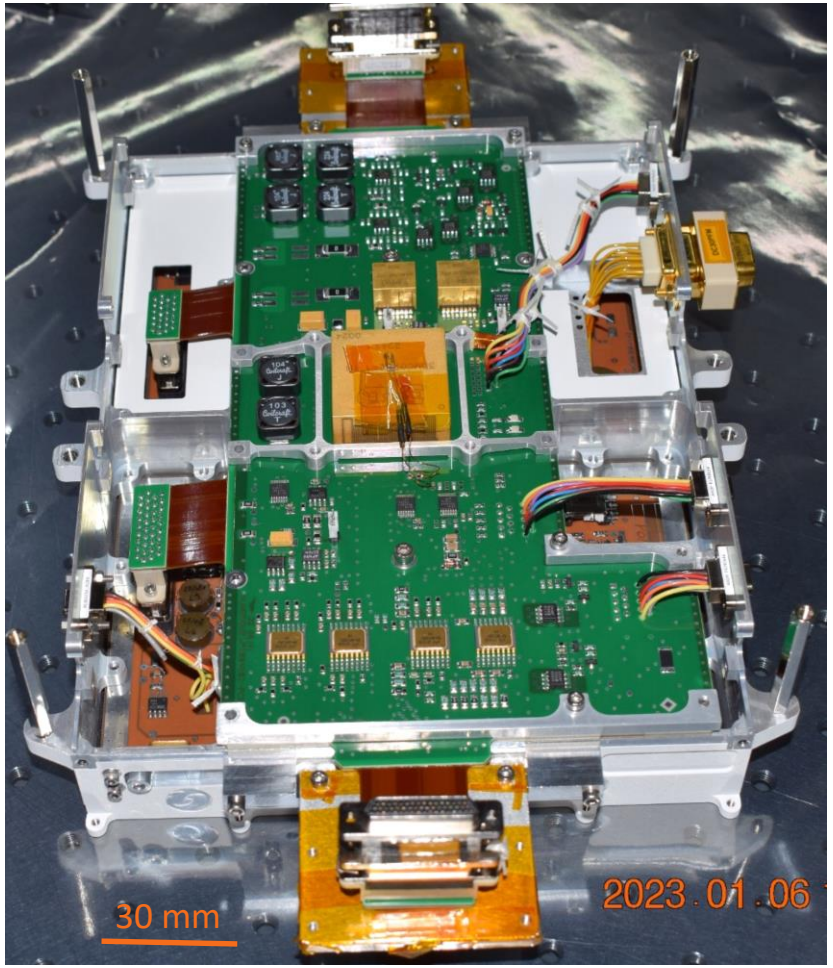


TM/TC Management

HK acquisition

Science signal processing

Science products generation



FUSIO RT ON THE MOON

DORN Instrument – Challenges in the Synthesis Process – 81% Full at 100 MHz

- DORN instrument is VHDL design is challenging (size and architecture)
  - FPGA matrix almost full with all the function needed (TM/TC Management, HK acquisition, Science signal processing, Science products generation)
  - Implementation of RIMC SDRAM and NAND Flash Memory controller
  - Implementation of internal resource sharing (multiple FIFOs implemented within one FPGA SRAM block)
  - 3 clock domains (25, 50 and 100 MHz)

Synthesis results

```
+-------------------------------------+
|     Configuration bits report       |
+-----------------+---------+---------+
| Total count     | 6189616 |   100 % |
| Total used      | 5038695 |  81.4 % |
| Total critical  |  456494 |  7.37 % |
+-----------------+---------+---------+
+------------+-----------+
| Total Size | 5.20Mbits |
+------------+-----------+
```

Reporting instances

4-LUT	DFF	XLUT	1 - bit Carry	Register file block	Cross domain clock	Clock Buffer	Clock switch	Digital signal processor	Memory block	WFG	PLL
16630/32256 (52%)	9268/32256 (29%)	0/2016 (0%)	4532/8064 (57%)	25/168 (15%)	0/0	0	0/336 (0%)	1/112 (1%)	37/56 (67%)	4/32 (13%)	1/4 (25%)

VHDL code statistics

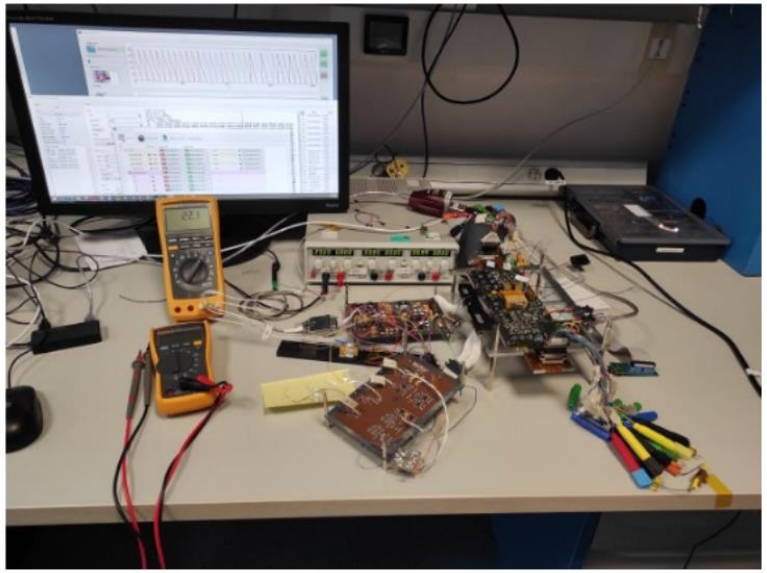
- 22 000 code lines (DORN + 3DPlus IPs)
- SPI, AXI, UART and custom serial protocols

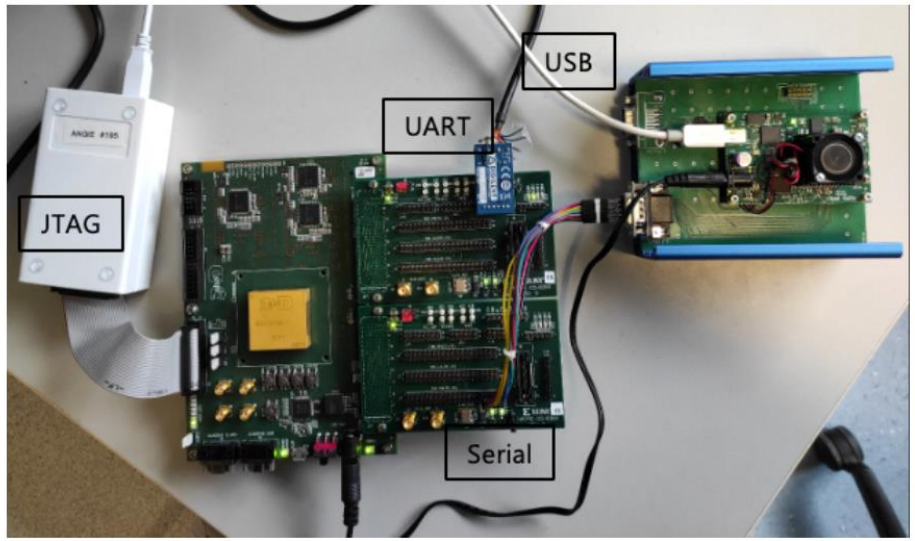
FUSIO RT ON THE MOON

Development Tools and Ecosystem for Application's Prototyping and Testing

Software tools

- SIGASI IDE
- NX map 3
- Mentor Questasim





Hardware tools

- Angie NX probe
- FUSIO-RT eval board
- Opal Kelly board with xilinx FPGA

FUSIO RT ON THE MOON

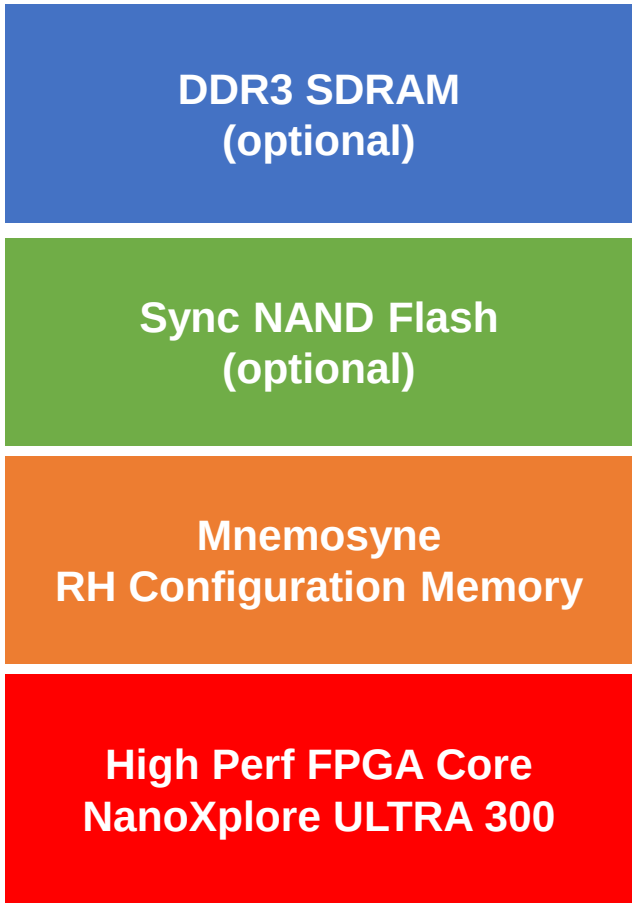
Conclusion and Introduction to FULTRA

- **FUSIO RT will be on the moon in 2024**
- FUSIO RT computer core product family embedding the **NanoXplore NG-Medium NX1H35S FPGA available since 2020**
- Space qualified solution and proven radiation hardened design
- High modularity solutions
- Multiple configurations with compatible footprint
- Board area, cost, design time reduction compared to all single parts considered separately
- FUSIO RT Ecosystem: Development Kit and firmware solutions for quick prototyping and development L/T reduction
- Already used in multiple designs by several customers in Europe, Asia and USA
- Upcoming Product Line Extension with FULTRA : a New High-Performance Computer Core embedding the NanoXplore ULTRA-300 FPGA

FUSIO RT ON THE MOON

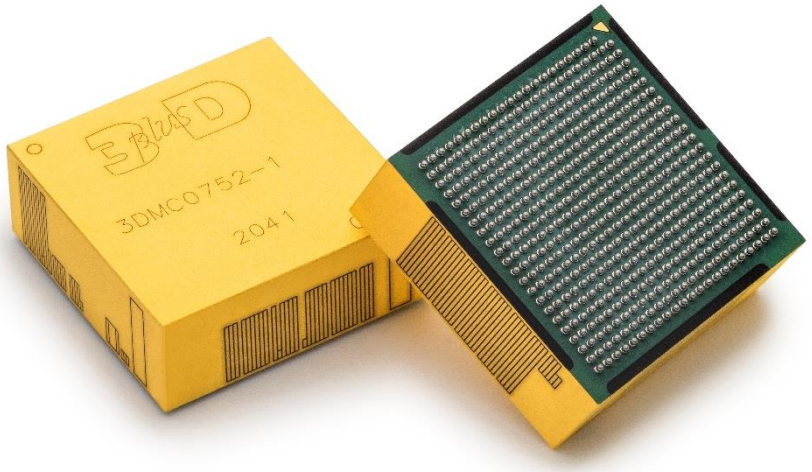
Introduction to FULTRA – Available in Q4/2024

- Digital Core : **NanoXplore NG ULTRA 300**
  - High end FPGA core
  - 405 user I/Os
  - High speed transceivers
  - Existing development ecosystem
- Integrated Configuration Memory
  - 256 Mb RH and SEE Immune Mnemosyne Memory ASIC develloped by 3D PLUS
- Optional memory layers
  - DDR3 SDRAM : 8 Gbit – 32b data bus at 800 MHz
  - Synchronous NAND Flash : 64 Gbit
- Temperature range: -55 to +105°C
- BGA 676 with 1mm pitch, LxWxH: 29 x 29 x10 mm
- Space qualified technologies & All-in-one solution
- **ITAR Free**



THANKS FOR YOUR ATTENTION

Any Question ?



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OUR MISSION IS THAT YOU ACHIEVE YOURS

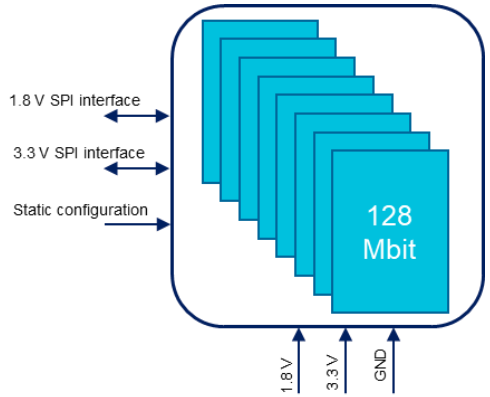
- Thanks to IRAP for the DORN Project Information
- Special Thanks to NanoXplore

MNEMOSYNE PRODUCT LINE

3DMN1G08US8854: High Density Rad-Hard NVM with serial interface

KEY FEATURES

- 1 Gb density (8 banks of 128 Mb)
- Up to 100 MHz
- Embedded ECC
- 1.8 V SPI interface
- SPI, QSPI, DSPI, OSPI modes supported
- 100 k P/E cycles
- 20 years data retention
- [-55 °C; +125 °C]: operating temp.
- SOP32 (TBC)
- Worldwide Delivery Guaranty



RADIATION PERFORMANCES

- TID > 100 krad(Si)
- SEL > 60 MeV.cm²/mg
- SEU > 60 MeV.cm²/mg
- SET > 60 MeV.cm²/mg
- SEFI > 60 MeV.cm²/mg

The SEE LET threshold would be tested in other facilities with 80 MeV.cm²/mg target